The infarct characteristics on magnetic resonance imaging and ventricular tachycardia: do we see what we need to see?

Katja Zeppenfeld* and Rob J. van der Geest

1Department of Cardiology, Leiden University Medical Center, Postbus 9600, 2300 RC Leiden, The Netherlands; and 2Department of Radiology, Division of Image Processing, Leiden University Medical Center, Postbus 9600, 2300 RC Leiden, The Netherlands

Received 7 January 2011; accepted after revision 10 January 2011; online publish-ahead-of-print 4 February 2011

This editorial refers to ‘The heart rate of ventricular tachycardia following an old myocardial infarction is inversely related to the size of scarring’ by L. Woie et al., on page 864.

The underlying mechanism of most ventricular tachycardias (VTs) after myocardial infarction (MI) is reentry involving areas of ventricular scar. Dense fibrous scars alone cannot cause arrhythmias; however, when surrounded by bundles of surviving myocytes in the peri-infarction zone, an arrhythmogenic substrate may arise. Areas of dense fibrosis intersperse with surviving myocardial bundles and form regions of conduction block that define reentry circuit borders. The presence of fibrosis between these surviving bundles prolongs the pathway for impulse propagation, creating slow conduction through the scar.1 The complex structure of these scars is likely to determine reentrant circuit characteristics and thereby VT characteristics.2

Late gadolinium-enhancement cardiac magnetic resonance (LGE-CMR) has increasingly been used to visualize the three-dimensional (3D) geometry of myocardial fibrosis and has become the gold standard for detection of non-transmural scars because of its superior spatial resolution.3 Woie et al.4 have addressed an interesting question of whether myocardial scar characteristics as visualized and defined by LGE-CMR correlate with VT characteristics, specifically with the VT cycle length (VTCL). They hypothesized that the rate of spontaneous VTs is related to the size of post-infarction scar or its border zone.

They studied 24 patients with remote MI and indication for implantation of an internal cardioverter-defibrillator for primary or secondary prevention who underwent LGE-CMR for quantification of left ventricular (LV) volumes, function, size of core infarct, and size of the infarct border zone prior to device implantation. Patients were followed every 3 months during the first year after implantation. Twenty out of 24 patients had VTs with a median VTCL of 325 ms (range 239–438 ms). None of these patients received anti-arrhythmic drugs that might influence VTCL. Ventricular tachycardia cycle length was correlated with five proposed LGE-CMR scar characteristics: size of the scar, size of core infarct and the scar border zone, contour regularity of the scar, and number of core islands within the scar area.

In univariate analysis, the scar characteristics that showed a strong correlation with VTCL were scar size, number of core islands, and size of the peri-infarction zone. Following the stepwise selection of different parameters (not fully described), the strongest positive correlation was found between VTCL and the core infarct size combined with the number of core islands. The authors concluded that large and dense scars assessed by LGE-CMR may prolong the time the excitation wavefront needs to propagate around the circuit.

In animal post-infarction models, it has been demonstrated that areas of slow conduction, which determine the reentry circuit isthmus, coincided with areas where layers of viable myocardium are the thinnest and layers of fibrosis are the thickest, and these areas correlated with greater scar transmurality on CMR.2 Ventricular tachycardia cycle length is determined by circuit path length and conduction velocity; an increasing isthmus length contributes to the circuit path length resulting in a longer VTCL.

Electroanatomical mapping studies in humans with VTs after MI have demonstrated isthmus lengths of 23 ± 11 mm for a VTCL of 374 ± 59 ms.5 Of interest, these isthmuses were found in very low-voltage areas (< 0.2 mV) assessed by bipolar voltage mapping. These low-voltage electrograms are usually found in areas with dense transmural infarction.6 These findings support an interesting correlation between slower VTs and larger scar areas, provided that these scars are transmural, and the authors should be encouraged to include scar transmurality in their analysis.

* Corresponding author. Tel: +31 715262020; fax: +31 715266809; Email: k.zeppenfeld@lumc.nl

The opinions expressed in this article are not necessarily those of the Editors of Europace or of the European Society of Cardiology.

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2011. For permissions please email: journals.permissions@oup.com.
Several studies have recently focused on the relationship between scar size and heterogeneity determined by LGE-CMR and inducible and spontaneous VTs. Infarct size was a better predictor of cardiac events and all-cause mortality than LV ejection fraction (EF) and volumes in ischaemic cardiomyopathy. In addition, both infarct surface and mass better identified patients who had a substrate for inducible monomorphic VTs than LVEF.

In these studies, a binary approach was used to categorize tissue into scar vs. normal myocardium. A scar was defined as any region with a signal intensity (SI) more than two standard deviations (SD) above the mean of a remote normal region. This definition of a scar has been validated in an ex vivo animal model which showed a nearly exact relationship between size and shape of infarcted myocardium detected by LGE-CMR and histopathology. However, for imaging in vivo, the spatial resolution is more than 100 times worse. Cardiac motion with consecutive blurring and partial volume effects can lead to overestimation of the total infarct size. In addition, scar definition depends on the choice of the remote normal zone. Suboptimal signal suppression of remote myocardium, image artefacts, and potential interstitial fibrosis may affect the SI of remote myocardium. An alternative approach employs 50% of the maximum intensity within infarct (full-width at half-maximum) as a threshold for a scar. However, this technique assumes the presence of a bright, dense core infarct, and may not be accurate enough if the infarct is inhomogeneous.

In the study by Woie et al., the total scar size was assessed manually with planimetry on each short-axis slice which might be prone to interobserver variability. However, the semi-automated methods may also not be objective because all require an operator’s input. For dense scars with homogeneous bright intensity, different methods seem to result in similar and reproducible infarct size measurements.

What about infarct heterogeneity as assessed by LGE-CMR? Post-infarction scars on CMR are characterized by differentiating the core infarct and the infarct border zone, also described as peri-infarct or grey zone, based on the spatial distribution of signal intensity. For this purpose, semi-automated methods have been used. Yan et al. identified a relatively large peri-infarct zone as a powerful predictor of mortality. Peri-infarct zone was defined as areas with an SI between 2 and 3 SD above SI of remote myocardium, normalized as a percentage of total infarct zone (area with an SI of >2 SD above remote myocardium). Schmidt et al. could demonstrate that infarct tissue heterogeneity expressed by the extent of the infarct grey zone, but not total infarct size correlated with inducibility of monomorphic VTs at electrophysiological testing. In this study, the core infarct was defined as areas with SI >50% of maximal SI in the hyperenhanced area and the infarct grey zone as myocardium with SI > peak SI of remote myocardium but <50% of the maximum SI.

Inducibility of VTs does not necessarily correlate with the occurrence of spontaneous VTs. Roes et al. found that the infarct grey zone as a measure of tissue heterogeneity was the strongest predictor for spontaneous VTs. Based on the potential limitation of using the peak SI of remote myocardium to define the grey zone, core infarct and grey zone were based exclusively on the maximum SI in the hyperenhanced area (core SI ≥50% of maximal SI, grey zone 35% ≤ SI < 50% of maximum SI).

Although not systematically evaluated, it seems unlikely that these different semi-automated methods will result in a similar delineation and quantification of heterogeneous infarct tissue and none of them has been compared with histopathology. Therefore, it is puzzling that Woie et al. introduced another method to define scar heterogeneity. In their study, core infarct was defined as the highest SI minus 2 SD of the visually determined scar area. However, it is not completely clear from the manuscript if this evaluation was performed for each slice separately, which would imply the potential variation in the core infarct SI per slice. If the core zone was separated by areas with lower SI—which would have been defined as a border zone by others—the definition ‘core islands’ was applied. Although the number of core islands correlated with VTCL, a similar correlation was already found for total scar. A complex border zone definition was used to provide a measure for contour regularity of the scar and to determine the size of the border zone after an arbitrarily performed dilation. However, none of these parameters seems to improve the correlation with VT characteristics, and as the authors state some correlations ‘may have been obtained by chance’.

Prior studies in humans have demonstrated that slow conduction takes place in narrow bundles of surviving myocytes surrounded by fibrous tissue. Details of the 3D infarct structure have been visualized by high spatial resolution LGE-CMR techniques performed ex vivo in a swine infarct model and related to VT reentrant circuit sites, but not to histopathology. Both isthmus and epicardial breakthrough sites were characterized by a complex structure consisting of multiple islands and protrusions of viable myocardium in the peri-infarct region. However, current in vivo LGE-CMR techniques with an inferior resolution and sources for false-positive and false-negative findings are unlikely to visualize the exact 3D scar geometry.

Despite these limitations, the authors have touched on a very important question of whether in vivo LGE-CMR-based visualization of scar characteristics can be related to VT characteristics. The identification and delineation of arrhythmogenic substrate by imaging would be fascinating and would facilitate recognition of patients at risk of VTs and substrate-based treatment strategies, such as catheter ablation. To date, the anatomical and histopathological basis for the different LGE-CMR-derived scar characteristics is not fully understood and the relationship of potential VT reentry circuits to the magnetic resonance imaging findings is still unknown. However, improvement of the spatial resolution of LGE-CMR and validation of LGE-CMR-derived scar characteristics in experimental models with histopathological correlation might overcome the current limitations.

Conflict of interest: none declared.

References
3. Wagner A, Mahrholdt H, Holly TA, Elliott MD, Regenfus M, Parker M. Contrast-enhanced MRI and routine single photon emission computed...


